STUDY GUIDE

ANAEROBIC DIGESTION

INTRODUCTION AND ADVANCED

SUBCLASS F

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PREFACE

This operator's study guide represents the results of an ambitious program. Operators of wastewater facilities, regulators, educators and local officials, jointly prepared the objectives and exam questions for this subgrade.

The objectives in this study guide have been organized into modules, and within each module they are grouped by major concepts.

HOW TO USE THESE OBJECTIVES WITH REFERENCES

In preparation for the exams, you should:

1. Read all the objectives that apply to the grade level desired and write down the answers to the objectives that readily come to mind.

2. Use the references at the end of the study guide to look-up answers you don't know. This one set of references covers all of the objectives.

3. Write down the answers found in the references to those objectives you could not answer from memory.

4. Review all answered objectives until you can answer each from memory.

IT IS ADVISABLE THAT YOU ATTEND SOME FORM OF FORMAL TRAINING IN THIS PROCESS BEFORE ATTEMPTING THE CERTIFICATION EXAM.

Choosing A Test Date

Before you choose a test date, consider the training opportunities available in your area. A listing of training opportunities and exam dates can be found in the annual DNR "Certified Operator," or by contacting your DNR District operator certification coordinator.

INTRODUCTION

INTRODUCTION TO ANAEROBIC DIGESTION

MODULE A: PRINCIPLE, STRUCTURE AND FUNCTION

CONCEPT: PRINCIPLE OF ANAEROBIC DIGESTION

1. List the benefits associated with anaerobic digestion.

2. Explain the process where waste entering a digester is converted to methane, sludge, and water.

3. Explain why digester gas is considered "dirty gas."

CONCEPT: STRUCTURE AND FUNCTION

4. State the main functions of primary and secondary digesters in a two-stage system.

5. List the types of digester covers.

6. State the function of the water seal on floating cover digesters.

7. Explain the purpose of corbels in digesters with floating covers.

8. List the normal types of pumps used to pump and recirculate sludge.

9. Explain the purpose of the following component parts:

   A. Flame Traps
   B. Drip Traps
   C. Pressure/Vacuum Relief Valve
   D. Pressure Regulator
   E. Check Valve
   F. Gas Meters
   G. Manometer

MODULE B: OPERATION AND MAINTENANCE

CONCEPT: OPERATION

10. List what operational factors affect the operation of an anaerobic digester.

11. List two reasons why digester mixing is important.

12. List the two main gases that compose digester gas, and give The approximate percentage range of each for a well working digester.

13. Discuss sludge characteristics that determine potential production of methane.

14. Describe the physical and chemical characteristics of well-digested sludge versus poorly-digested sludge.

15. Outline the general start-up procedures for anaerobic digesters.

16. List the items to check before starting a positive displacement (piston, diaphragm, or progressive cavity) pump.

17. List the consequences of operating a positive displacement piston pump against a closed valve.

18. List what happens if a progressive cavity pump is pumping against a closed valve.

19. List what happens when a progressive cavity pump is run dry.

20. Discuss how an operator can increase or decrease the output from a piston or progressive cavity pump.

21. List two ways of heating digesters.

22. Explain the operation and ranges for mixing, heating, feeding, pH control, and volatile acid to alkalinity ratios, for an anaerobic digester.

23. Explain the affect temperature has on the rate of digestion.

24. Discuss the maximum temperature of water going into internal digester coils, and why this should not be exceeded.

25. Discuss the recommended rate of temperature change in degrees per day when changing digester temperature.

26. Describe gas flame color when a digester is working well, and when it is starting to go "sour."

27. List three ways to mix digester contents.

28. Explain the affect on Gas Production, Volatile Acid Production, and Alkalinity, if the feed rate to a digester is suddenly reduced.

29. Compare the time necessary to digest sludge in a heated mixed digester, and in an unmixed digester.

30. Explain why it works better to feed small amounts of thick sludge more often, than to force large amounts of thin sludge less often.

31. List the chemicals used to adjust digestor pH, giving the common name and chemical formula.

32. Identify where supernatant is returned, and describe the impact on plant operation.

33. State how long mixers should be turned-off in a fixed cover digester to ensure good supernatant when pumping sludge.

34. List the reasons why grit accumulation in a digester is undesirable.

35. Explain why some digested sludges will dewater more readily than others.

36. List the reasons why thick scum blankets will have adverse affects on digester operations.

37. Describe the proper method of sludge withdrawal from a fixed cover single-stage digester, and state the necessary steps taken to reduce the hazard of fire or explosion.

CONCEPT: MAINTENANCE

38. State the approximate time intervals that digesters should be drained, cleaned, inspected, and repaired.

39. List the proper maintenance steps for sludge draw-off lines after sludge is removed from the digester.

40. Describe the basic maintenance procedures for a piston, progressive cavity, and a centrifugal recirculation pump.

41. Outline the procedure used to remove check balls for inspection or replacement.

42. Discuss the basic maintenance for gas mixers and mechanical mixers.

43. Describe the basic maintenance for pressure/vacuum relief valves.

44. State how often operators should drain drip traps, and discuss the consequences if this is not done.

45. Describe the consequences of continued use of uncleaned flame trap baffles.

46. Describe the basic maintenance for flame traps and state the frequency of cleaning.

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MODULE C: MONITORING AND TROUBLESHOOTING

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CONCEPT: MONITORING

47. Explain how to get representative samples for feed sludge, digested sludge, supernatant, volatile acids/alkalinity, and digester gas.

48. Select the laboratory control test that indicates food available for digester bacteria.

49. List the tests that should be run to monitor digester operation.

50. Give the approximate values for BOD and Suspended Solids for a "typical" digester supernatant.

CONCEPT: TROUBLESHOOTING

51. Define what is meant by a digester upset.

52. Describe what should be done to a gas handling system after a sludge foaming incident.

53. Outline an action plan to use if the digester is starting to become upset or go "sour."

54. Discuss the important items to consider when correcting digester mechanical or structural problems.

55. Explain the possible causes and corrective actions for a gas burner that keeps going out.

56. Explain the possible causes and corrective actions for a digester cover floating unevenly.

57. Explain the possible causes and corrective actions for water getting into a gas meter.

58. Explain the possible causes and corrective actions for a sudden loss of gas production combined with a low volatile acid concentration.

59. Explain the possible causes and corrective actions for a gradualloss of gas production combined with a high volatile acid concentration.

60. Explain the possible causes and corrective actions for intense digester foaming.

61. Discuss what happens when check balls are not seating properly.

62. Discuss what happens when items such as sharp bone chips or other cutting abrasives are pumped through a progressive cavity pump.

MODULE D: SAFETY AND CALCULATIONS

CONCEPT: SAFETY

63. Explain why there should be a way of shutting-off sludge pumps from an area other than where the pumps are located.

64. List the personal safety equipment that should be on-hand before entering a digester for cleaning or repair.

65. Describe the chemicals used in controlling digester pH, including, the storage and handling concerns for:

    A. Calcium Oxide
    B. Calcium Hydroxide
    C. Anhydrous Ammonia
    D. Ammonium Hydroxide
    E. Sodium Carbonate
    F. Sodium Bicarbonate
    G. Sodium Hydroxide

66. Explain why air should never be allowed to mix with methane.

67. Discuss how air and methane could be mixed in a fixed cover digester, and define the precaution to minimize the condition.

68. Discuss how air and methane could be mixed in a floating cover digester, and define the precaution to minimize the condition.

CONCEPT: CALCULATIONS

69. Given data, calculate how many British Thermal Units (BTU's) are required to heat sludge to operating temperature.

70. Given data, calculate the amount of sludge that has been pumped based on the change in height of the floating cover.

71. Given data, calculate the volume (gallons) of a digester.

72. Given data, calculate a sludge recirculation rate in GPM.

73. Given data, calculate the volume (gallons) of sludge pumped from a piston pump.

74. Given data, calculate the change in volume (gallons) when the sludge concentration changes.

ADVANCED

ADVANCED ANAEROBIC DIGESTION

MODULE A: PRINCIPLE, STRUCTURE AND FUNCTION

CONCEPT: PRINCIPLE OF ANAEROBIC DIGESTION

1. Contrast the environmental sensitivity of acid forming bacteria to that of methane forming bacteria.

2. Describe the meaning of "digester buffering capacity," as it relates to digester control.

3. List the typical values for volatile acids and alkalinity in a well operating digester.

4. Compare thermophilic bacteria digester operation to mesophile bacteria digester operation.

5. State the expected reduction in volatile solids from a well operated digester.

CONCEPT: STRUCTURE AND FUNCTION

6. List three types of digester mixing systems.

7. Describe the function of gas compressors, and explain why they are used.

8. Describe the two methods of storing digester gas.

9. Describe a floating cover position indicator, and an alarm system.

MODULE B: OPERATION AND MAINTENANCE

CONCEPT: OPERATION

10. List the start-up procedures of a digester using seed sludge.

11. List the start-up procedures of a digester without seed sludge.

12. Define the organic loading rates for a conventional and a high rate digester.

13. Explain the impact on the following if a digester is hydraulically overloaded due to pumping thin sludge:

    A. Heating
    B. Supernatant
    C. Gas Production

14. Compare digestion time when operating at 85^{o}F., and at 95^{o}F.

15. Discuss methods of improving a digester's ability to hold its temperature during winter months.

16. Discuss operational alternatives when it is difficult to hold constant digester temperature in very cold weather.

17. Explain the impact on the following if a digester is being organically overloaded:

    A. Gas Composition
    B. Volatile Acids Concentration
    C. Total Alkalinity
    D. pH
    E. Gas Production

18. Explain why the ratio of volatile acid to total alkalinity is more sensitive to digester changes than is the pH test.

19. Identify the volatile acid to alkalinity ratios for the following:

    A. A continuously underfed digester
    B. A continuously overfed digester
    C. The point at which operator should take action
    D. The point at which pH will start dropping

20. State the gas pressure manometer reading in inches of water for a typical digester.

21. State the methane concentration level in digester gas when combustion can occur.

22. Explain why digester gas has an approximate fuel value of 600 BTU's compared to 1000 BTU's of pure methane.

23. Discuss why hydrogen sulfide and moisture is removed from digester gas.

24. Describe how to select the level for supernatant withdrawal.

25. Discuss the supernatant removal strategies for the following mixed and heated digesters:

    A. Single Fixed Cover
    B. Single Floating Cover
    C. Two-Stage with at least one floating cover

CONCEPT: MAINTENANCE

26. Develop a maintenance schedule for weekly, monthly, quarterly, and semi-annual activities.

27. Discuss procedures for complete digester cleaning.

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MODULE C: MONITORING AND TROUBLESHOOTING

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CONCEPT: MONITORING

28. Explain how to use the quantity of gas production as an indicator of digester performance.

29. Describe a method of analysis of digester gas composition.

30. Outline procedure for finding percent solids concentration of sludge and percent volatile solids.

31. Describe the locations for obtaining samples for the following:

    A. Feed Sludge Volatile Solids
    B. Digester Efficiency
    C. Volatile Acid To Alkalinity Ratio
    D. Digester Gas Composition

32. Describe how heat transfer efficiency is determined for internal heating coils.

33. Describe how to determine the amount of alkalinity needed to correct an upset digester, including chemical feeding rate.

CONCEPT: TROUBLESHOOTING

34. Identify the causes and corrective actions for the following gas system problems:

    A. Gas Pressure Lower Than Normal
    B. Gas Pressure Higher Than Normal
    C. Waste Gas Burner Problems
    D. Gas Meter Failure

35. List the methods for testing for digester gas leaks.

36. Identify the causes and corrective actions for the following pump problems:

    A. Plugging
    B. Motor Runs, But Is Not Pumping
    C. Drive Motor Stops

37. Identify the causes and corrective actions for the following mechanical mixing equipment problems:

    A. Shaft Seal Leaks
    B. Gear Reducer Wear
    C. Internal Mixing Parts

38. Discuss problems associated with control of scum blankets.

39. Discuss the toxicity concerns of the following:

    A. Heavy Metal
    B. Sulfides
    C. Ammonia
    D. Alkaline Salts

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MODULE D: SAFETY AND CALCULATION

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CONCEPT: SAFETY

40. Describe the storage and handling concerns for the following chemicals:

    A. Calcium Oxide
    B. Calcium Hydroxide
    C. Anhydrous Ammonia
    D. Ammonium Hydroxide
    E. Sodium Carbonate
    F. Sodium Bicarbonate
    G. Sodium Hydroxide

41. Discuss the relative safety of the chemicals used to adjust digester pH.

CONCEPT: CALCULATIONS

42. Given data, find how much seed sludge is needed for a particular digester.

43. Given volumes and concentrations, calculate impact of digester supernatant on plant loading.

44. Given volumes of feed sludge, sludge concentrations, volatile solids and volume of a digester, calculate the organic loading rate.

45. Given data, calculate the amount of time to recirculate the volume of sludge in a digester.

46. Given data, calculate percent efficiency of an anaerobic digester.

47. Given gallons of sludge pumped, sludge concentration, and volatile solids in and out of the digester, estimate digester gas production.

48. Given data, calculate the volume in cubic feet and gallons of a digester.

49. Given data, calculate the theoretical hydraulic detention time of a digester.

50. Given data, calculate for changes of volumes or concentrations of sludge.

RESOURCES

1. **ADVANCED WASTE TREATMENT**. 1st Edition (1987), Kenneth D. Kerri. California State University, 6000 J Street, Sacramento, CA 95819-6025. Phone (916) 278-6142.

2. **ANAEROBIC SLUDGE DIGESTION**. Zickenfoose, Charles and Hayes, R.B. Joe. Operations Manual EPA 430/9-76-001 (1976). U.S. Environmental Protection Agency, Office of Water Program Operation, Washington, DC 20090.

3. **CONTROLLING WASTEWATER TREATMENT PROCESSES**. (1984). Cortinovis, Dan. Ridgeline Press, 1136 Orchard Road, Lafayette, CA 94549.

4. **OPERATION OF MUNICIPAL WASTEWATER TREATMENT PLANTS**. Manual of Practice No.11 (MOP 11), 2nd Addition (1990), Volumes I, II, and III. Water Environment Federation (Old WPCF), 601 Wythe Street, Alexandria, VA 22314-1994. Phone (800) 666-0206. (MOP 11, 1976 can still be used as a reference)

5. **OPERATION OF WASTEWATER TREATMENT PLANTS**. 3rd Edition (1990), Volumes 1 and 2, Kenneth D. Kerri, California State University, 6000 J Street, Sacramento, CA 95819-6025.Phone (916) 278-6142.

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